Monitoring for auroral propagation

by P. K. BLAIR, G3LTF*

A brief outline of auroral occurrence

Anomalous vhf propagation by reflection from an intense ionization in the E region of the ionosphere by auroral processes has been known to amateurs for more than 40 years. Its usefulness in making long-distance contacts has been demonstrated on all the vhf/uhf bands up to and including 432MHz, and it is probably only a matter of time before a 1,296MHz contact is reported as it is known that the reflections are effective well beyond 3GHz, having been observed there by radar. The attraction of the mode is in some ways even greater than that of dx tropo propagation in that the QRM level is usually low and there is a high degree of geographical selectivity (similar to the "skip" effect on the hf bands). Hence some unexpected and rare countries turn up via aurora which are probably inaccessible by modes other than eme or meteor scatter.

The occurrence of auroral propagation is closely linked to the 11-year sunspot cycle and to some extent concentrated about the equinoctial periods, although some of the best auroras to date have occurred outside these. The mechanism of the aurora is complex and only a brief outline of it will be given here. For further background the reader is referred to [1].

Following the occurrence of some sort of explosion on the sun in which a solar flare occurs, large quantities of charged particles are thrown off. The flare is usually, but not always, associated with a sunspot group. The particles possess sufficient energy to travel the 93 million miles separating the earth from the sun and are accelerated towards the earth by attraction from its magnetic and gravitational fields. Of course, if the outburst occurs on the surface of the sun facing away from the earth then there is little chance of an aurora occurring. From the amateur's viewpoint, the best situation is for a flare to occur at the point on the sun's surface facing the earth. Note, incidentally, that the sun's surface rotates with an equatorial period of about 27-28 days with a slightly slower rate at latitudes near to its poles.

Concurrently with the flare there is likely to be a large increase in the solar noise level which can be observed at radio frequencies, for example in the way demonstrated by Ron Ham at Storrington, Sussex. However, this is not always a reliable warning although the author has the feeling that all major auroras could be predicted in this way.

* 1 Potter Street, Harlow, Essex.

When the stream of particles nears the earth they become trapped in the magnetic fields associated with the Van Allen belts and are guided by them towards the polar regions. They spiral down to around the E region where they give up part of their energy by collision and ionize the molecules which make up the E layer. This highly increased level of ionization allows the E layer in that region to reflect signals of a much higher frequency than normal, analogous to the reflections in summer known as sporadic-E.

Another effect of the solar flare is to release large quantities of X and gamma rays which are mostly absorbed in the D region of the ionosphere before reaching the earth's surface. This causes the radio blackout or Dellinger fadeout which affects propagation in the 3-30MHz region immediately following the flare

The reader will see from this brief description of the auroral mechanism that there are a wide variety of effects which could be used to predict the onset of an auroral opening. These will be discussed in the following section which will also assess the reliability with which they may be used to anticipate auroral propagation at vhf.

Methods of anticipating auroral occurrence

This section will examine ways in which the amateur can anticipate auroral propagation conditions; continuous monitoring of the low end of the 144MHz band is ruled out as being too time consuming.

Visual

Starting with the sun itself, visual monitoring for sunspots is perfectly practicable—British weather permitting. This can be done by using a small telescope or a pair of binoculars and displaying the image on a white card. A larger piece of card as a shield against the direct light, with a hole for the telescope, would be useful. In no circumstances should the eye be in any way exposed to the light from the eyepiece, even with a home-made filter, or serious eye damage could result. The sun's image will, if there is some activity, show dark spots, often in clusters, which will pass across the disc, taking about 10 days to do so. Large groups of spots are a good sign of aurora, as is their sudden appearance. The nearer to the solar equator, the more likely is the spot to influence the ionosphere. However, the shortcomings of this method are obvious—limited observation time and no direct correlation between observation and effect.

Magnetic

A solar outburst has a direct effect on the earth's magnetic field. This can be observed as a sudden change in dip angle, that is the angle which a magnet makes to the vertical when suspended at its centre point on a horizontal pivot. This change is very small, far less than one degree of arc, and consequently it is difficult to detect without special equipment. A strong change would appear to correlate well with the occurrence of a magnetic storm, which again is likely to coincide with the onset of the aurora.

Induced currents

It is well known that in the days before the effects were understood, magnetic storms caused considerable trouble to the telephone companies by inducing strong out-of-balance currents into certain lines. Measurement of these currents,

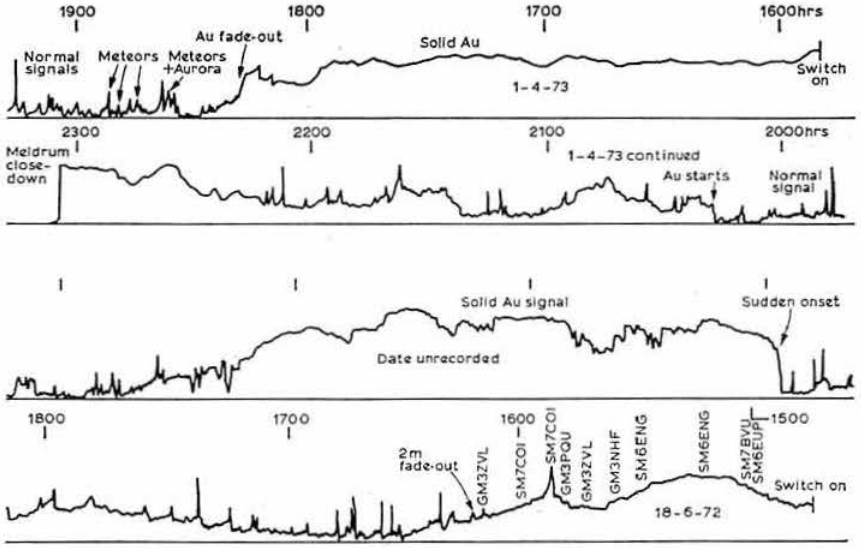

Fig 1. Some typical auroral signal recordings

which can produce measurable voltages on long lines, has been used in conjunction with auroral monitoring but it should be noted that to connect apparatus to the Post Office lines is against the law in Britain.

Radio effects

(a) HF fadeout

This well-known effect is sometimes called the Dellinger effect after its first observer. To the operator on 28, 21 and 14MHz it is a nuisance but it can serve as a prompter to look at vhf. The symptoms are a very rapid fadeout of all but local, groundwave, signals from the high frequency end of the spectrum downwards. By high frequency is meant the maximum frequency at which F layer propagation is occurring; the lowest affected frequency depends on the time of day and the intensity of the solar storm. The effect can be very rapid with a fadeout rate of some 40dB over a 3min period. Propagation returns at a much slower rate, typically ½ to 1h, and then with a very fluttery hollow-sounding note to the signals.

The Dellinger fadeout is caused by the sudden ionization of the D layer and is coincident with the arrival of [the fast-moving high-energy particles emitted by the solar outburst some 3min after it leaves the sun. The slower particles take much longer and so the onset of vhf aurora is delayed on the Dellinger by anything up to 30h. More than one fadeout may occur because a very active group of spots will produce a succession of flares. This tends to put the hf bands into a low state of health for some days.

The vhf operator who is also an experienced and regular hf operator will be sensitively alert for these effects. The more casual operator may not be. The author has tried continuous recording of the 6MHz transmission from Radio Luxembourg but, though fadeouts did occur, they were not always easy to spot on the chart and sometimes occurred when the transmission was off.

(b) D layer ionization

D layer ionization is responsible for another propagation effect which should be measurable by amateur equipment, though the author has not attempted it. This effect is known as the "sudden phase anomaly" (spa). An lf signal is propagated by ground waves in the space between the earth and the ionosphere, forming a "waveguide". When the D layer is strongly ionized the waveguide height drops suddenly and the phase of the signal received undergoes a change.

This can also be regarded as a sudden change of phase between a direct (strong) and indirect, reflected (weaker) signal. By observing the phase of the Droitwich transmission on 200kHz against the phase of a stable oscillator, counted down from 1MHz, a phase anomaly should be readily observable on top of any phase cycling due to the slight drift of the local standard against the Droitwich signal.

(c) Solar noise

Observation of solar noise level on a regular basis, as described by Ron Ham and others, can give adequate warning of the solar outburst. The author feels sure that with experience amateurs can become expert in interpreting the record so as to be able to guess fairly accurately which level increases are significant. Casual observation will not be enough, but any sudden outbursts—and they can be very strong—should give an alert to the vhf operator that auroral happenings are imminent. Solar noise can be observed on any convenient and locally clear frequency above about 30MHz. There are components below this frequency but they tend to be masked by other noise sources except when extremely strong.

(d) VHF transmission effects

After trying several of the above ways of anticipating the onset of auroral propagation conditions at vhf, the author came to the conclusion that the only way to avoid false alarms and missed auroras was to use a more direct method,

that of detecting auroral effects on a vhf transmission. No novelty is claimed for this approach and it is used by a few others in the UK. What is required is a transmission in the low vhf region, so that it will go auroral before 144MHz does, and in the northerly direction rather than north-east or north-west. The author has yet to hear an aurora where GMs and the north of England were *not* prominent, whereas for stations east and west the geometry is more critical and the chances of missing an aurora are much greater. For example, the fm transmissions from eastern Europe which appear on 70MHz during the sporadic-E season are poor as advance warnings, as are the 144MHz beacons of which very few come through regularly on aurora.

Convenient transmitters are provided by vhf tv sound transmitters. Although nominally all are on "spot" channels (1, 2, 3, etc) the sound carriers of stations using the same channel are separated from each other over a range of about 50kHz. This means that even with a relatively strong "local" signal the more distant transmissions can be separated out. For example, on Ch 4 (58·25MHz) there are five or six separate identifiable signals. Locally, relatively speaking, there are Manningtree and Sutton Coldfield; others are Wenvoe and, the two of most use to aurora spotters, Meldrum and Carlisle.

The Meldrum transmitter is without doubt the most reliable indicator of aurora. Its frequency is some 35kHz lf of Sutton Coldfield and being so far to the north and with a good part of its transmission aimed that way, it comes through in the south when there is the faintest trace of aurora about. It may be that in some parts of the country the signal from Meldrum is obliterated by the remnants of the vestigial attenuated sideband of the adjacent channel vision. The author has used his Meldrum monitor in several areas of eastern England and on the Black Mountains in South Wales without experiencing any trouble. If this were a problem the Carlisle transmission, 19kHz hf of Sutton Coldfield, can be tried. The author has noticed Carlisle coming through well during auroras but not as strongly as Meldrum.

With regard to the "normal" signal level from Meldrum, the author believes that at a range of some 350 miles it is mainly troposcatter with aircraft reflections noticeable. Many meteor pings and bursts occur, on average about 5-10/min, and there are occasional extended tropo ducts, though these are much rarer than on 144MHz. The average signal is around 6dB over noise in 1kHz with a simple antenna. When aurora occurs the signal comes up by anything up to 40dB with a rasping growl that spreads 10kHz or more and is quite unmistakable. Levels of around 6-10dB of auroral signal do not seem to produce 144MHz reflections,

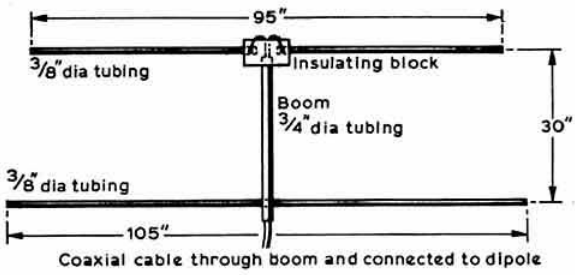

Fig 2. Meldrum aerial

Components list

C1, C4	6·8pF ceramic	**R1**	5·6kΩ
C2, C5, C11, C24	12pF tubular trimmers	**R2**	18kΩ
C3, C16	0·5pF ceramic	**R3, R5**	100Ω
C6	390pF ceramic	**R4, R9**	1kΩ
C7	1-10pF tubular trimmer	**R6**	82kΩ
C8, C10, C18, C22	1,000pF feedthrough capacitors	**R7**	2·2kΩ
C9, C21	1,000pF ceramic	**R8**	68Ω
C12	4·7pF ceramic	**R10**	4·7kΩ
C13	33pF ceramic	**R11**	6·8kΩ
C14	22pF (to suit ift L4)	All ¼ or ⅛W carbon	
C15	3,300p disc ceramic		
C17	0·01μF 15V	**TR1**	GMO290 or similar low noise—AF 139, AF 239
C19	180pF ceramic		
C20	18pF ceramic		
C23	0·22μF 15V	**TR2**	2N3819
		TR3	2N3904

L1 10 turns ⅛in id 18g enam close-wound tapped 2t up
L2 As L1 but tapped 4t up
L3 11 turns ⅛ id 18g enam close-wound tapped at one turn and five turns from cold end
L4 I.F. transformer appropriate to crystal chosen
L5 Six turns 20g on ¼in slug tuned form (for 65MHz crystal)
L6 Nine turns ¼in id spaced wire diameter

though as an aurora dies away it can sustain 144MHz when Meldrum is only at this level.

Fig 1 shows some typical recordings of Meldrum signal levels. A sudden onset of the auroral signal, say within 2min, will almost always indicate 144MHz aurora within 10-15 min or less. The more gradual onsets are sometimes delayed 30min or more. Only rarely does no 144MHz aurora result. On 70MHz no time should be lost as there is not even 10-15 min warm-up time! VHF auroral openings frequently run in phases, with an opening around 1500 and then at around 1700 and again near 2200-2400. By recording the signal on paper tape from midday onwards, the working vhf operator can be warned when he returns home.

The only snag with Meldrum is that it is switched off at the end of television transmissions but often there is a clue from the signal behaviour before closedown and from what has occurred earlier in the evening. Few auroras put in their first appearance after midnight; occasionally, however, some do, and the author does not yet know how to be alerted for them.

Equipment

The equipment which the author has used for monitoring the Meldrum transmission comprises a simple horizontally-polarized two-element beam, radiator plus reflector, mounted at about 18-20ft above ground and pointing roughly north (Fig 2). This is fed to the converter which is quite conventional and uses a convenient crystal to give an i.f. of around 7MHz. The circuit diagram and layout are shown in Figs 3 and 4.

Alignment consists of first making the oscillator work, and checking that it is crystal controlled by listening to it or its harmonics on a suitable receiver. The signal circuits are then peaked for maximum level on the strongest of the signals received and finally the input is tweaked for best s:n ratio on the desired weak signal. The 144MHz trap is tuned

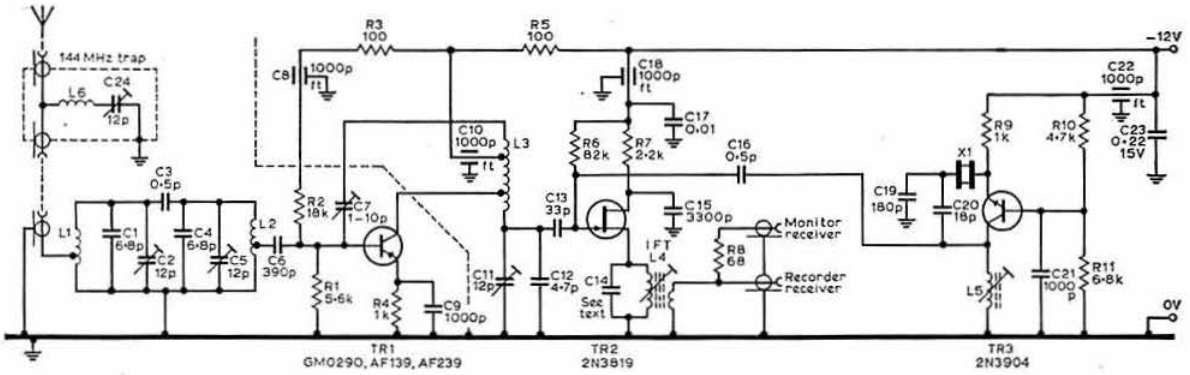

Fig 3. Circuit diagram of converter

up in front of a 144MHz converter with a simple attenuator between it and the converter to avoid instability.

Two outputs are available from the converter. One goes to a fixed-frequency simple receiver made from a Mullard module i.f. strip and 7MHz mixer with variable oscillator. The i.f. strip agc is measured by a simple dc amplifier driving a meter—in effect a near-conventional S-meter. However, if a spare receiver is available in the station, this can be used. The author takes the second converter output to an R1475 which enables detection of the slight growl (only a few decibels over noise) which can mean that aurora is about and may turn up the next night.

Variations on the converter design are possible; for instance, the rf stage could use a fet. One point worth noting is that the 144MHz trap stops the 144MHz transmitter from blocking the receiver, which can be annoying if a recording is being made.

General auroral operating hints

First, be ready for repetition of the previous auroral opening on a 26/29-day period—as the area on the sun's surface comes round again it may still be active and give a second auroral opening. This can conveniently be done by plotting any auroral events noted on a 27-day chart; their recurrence, if any, will show up as a near vertical line. In particular, be on the lookout in the months of February-May and September-November.

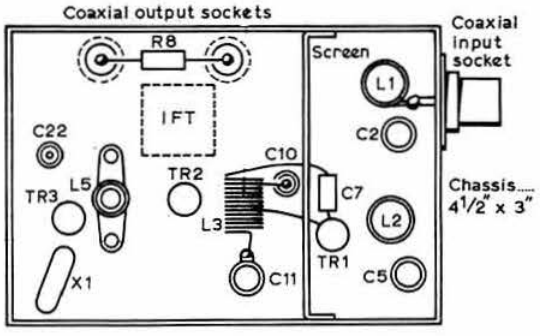

Fig 4. Layout of principal components

Second, if possible always check the monitor in mid-afternoon and early evening, and again around 2200. These seem to be the times when aurora is most likely to be present; the author has rarely heard any in the 1900-2200 period.

Third, if you are fortunate enough to be in at the beginning of an opening, look first at the easterly bearings—sometimes almost due east. This is where the real dx comes in and use can then be made of the wide E-W spacings. The strong GMs will be there later and they will also be looking for easterly dx.

Fourth, give a call on 432MHz; aurora works on that band too but our narrow antennas cause the problem of where to aim the beam. The use of stacks or other antennas with wide azimuth beams would do a lot to boost the auroral QSO rate on 432MHz.

Fifth, use cw. The QSO rate is much higher, and there is no question that the real dx auroral signals, over 1,100 miles, are weak. The very distant ranges are highly non-optimum in their reflection geometry and hence, by definition, signals can only be weak.

Reference

[1] J.A. Ratcliffe, *Sun, Earth and Radio*, World University Library, 1970. □

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